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Assessment of WRF surface layer formulations over a complex terrain in a tropical region

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The accurate and efficient estimation of surface turbulent fluxes is crucial to predict an adequate atmospheric evolution by atmospheric numerical models. The Monin-Obukhov similarity theory, which is used to compute these fluxes in numerical models, utilizes the empirical stability correction functions. In the present study, impact of various functional forms of these similarity functions for momentum and heat on the computation of the surface fluxes under both unstable and stable stratification is analyzed. In addition, this study compares two surface layer parametrization schemes in the Weather Research and Forecasting model over a tropical site Ranchi (India). The model is run with three nested domains at a high resolution (1 Km) for 'five' 4-day periods covering 15 days of Premonsoon season. The two surface layer parametrization schemes chosen for the analysis includes MM5 surface layer scheme having Businger-Dyer similarity functions and revised MM5 scheme utilizing the functions those are valid for full ranges of atmospheric stabilities. The five planetary boundary layer (PBL) schemes are selected to assess the influence of the surface layer parametrization schemes on the structure of the boundary layer. The five schemes includes- the Asymmetric Convective Model Version 2 (ACM2), Bougeault-Lacarrere (Boulac) PBL, Medium Range Forecast (MRF) PBL, Mellor-Yamada-Nakanishi-Niino (MYNN) PBL, and Yonsei University (YSU) PBL schemes. The impact of surface layer parametrizations in the near surface diagnostic variables are analyzed and compared with the observations obtained from slow and fast response sensors. The bias in the 2 m temperature (T2) and 10 m wind speed across the PBL schemes is very small and each PBL scheme is able to reproduce the diurnal variation of T2 irrespective of the surface layer scheme used for the simulations. A relatively higher value nocturnal 2 m temperature is predicted by the model with the revised MM5 surface layer scheme as compared to that obtained with the old MM5 scheme while both the surface layer schemes reproduce almost similar 2 m temperature during convective conditions. The revised MM5 scheme produces higher (lower) values of frictional velocity during the day (night) than the old surface scheme. The sensible heat flux does not depict significant variations in the revised surface layer scheme. A significant intra-scheme variance in the prediction of PBL height is observed. In comparison with the observations, the model is able to capture the observed 2 m temperature and 10 m wind speed during daytime convective conditions with a reasonably good accuracy with the revised MM5 surface layer scheme. However, each of the PBL scheme is found to overestimate the 2 m temperature and 10 m wind speed in comparison with the measurements with both the revised and old MM5 surface layer schemes during nighttime stable conditions. The daytime upward sensible heat flux is overestimated by all the PBL schemes with almost same magnitude of bias for the study period over the region. The present study suggests that the revised MM5 surface layer formulation is not able to reduce the bias in surface layer variables significantly over tropics and reasons for this are critically analyzed.